Architectural finishes

—a roundup of ideas and techniques

by the Editors of CONCRETE PRODUCTS

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Architecturally, the precast concrete panel has caught everyone's fancy; caught it and held it because of the tremendous variety of finishes a precaster can render on a concrete surface. Some of these finishes are costly to apply, others are relatively simple and inexpensive. All, however, require some extra skill and care and time. This article will probe the entire field of architectural finishes for concrete and will discuss both finishing ideas and techniques.

There are three basic ways a producer can improve or change the appearance of concrete:

- He can vary the materials, for example, by using a colored matrix, or special aggregates which are then exposed.
- He can change the mold or form in which the concrete is cast by using, for instance, a form liner.
- He can treat or tool the concrete after, or in the final stages of, hardening by sandblasting or bushhammering.

The idea is to develop and derive maximum benefit from one or more of three features—color, texture, pattern—all of which are interrelated.

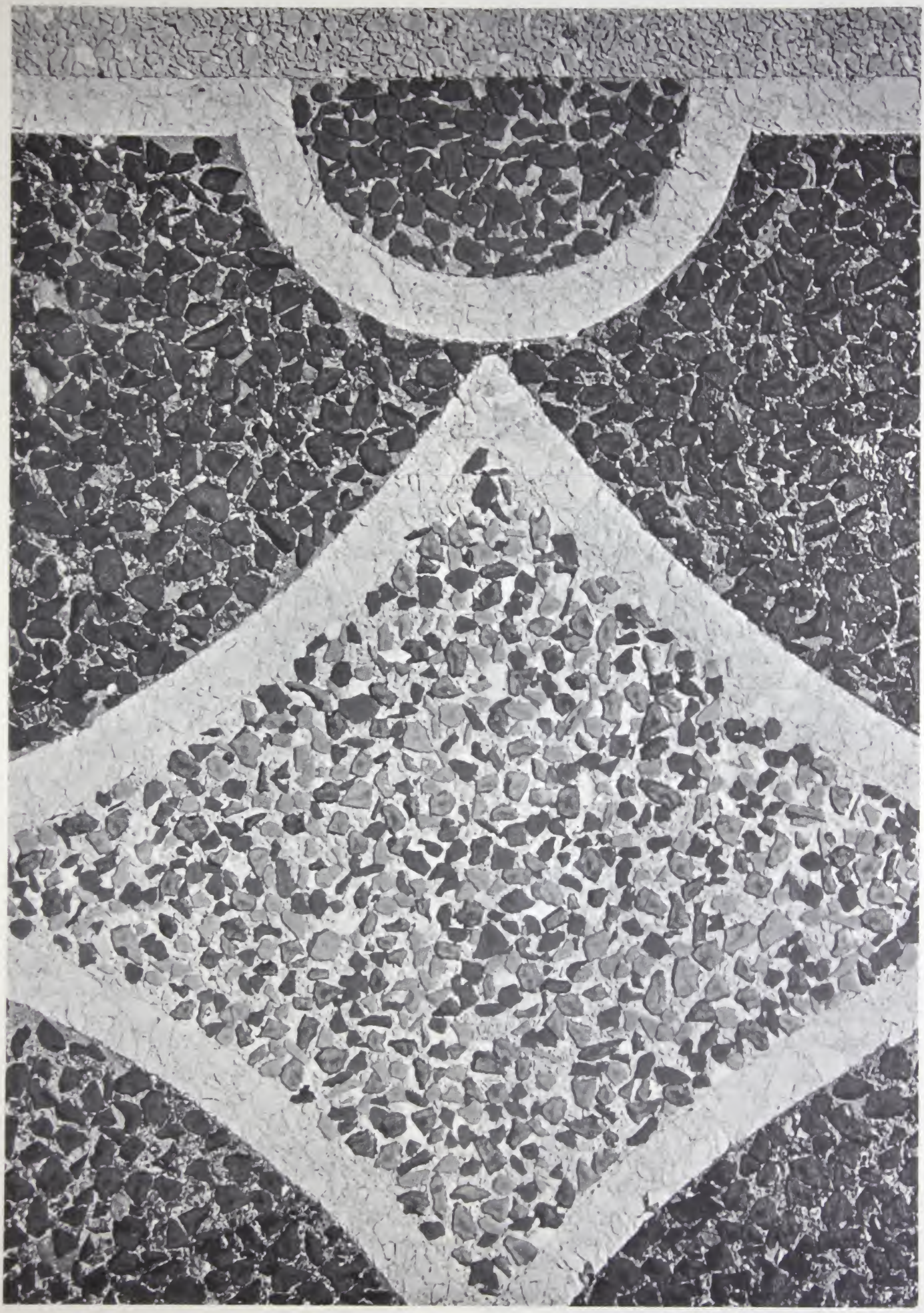
Color obviously provides one of the easiest means of changing the appearance of concrete. Various proprietary mineral oxide and synthetic pigments are available to give a range of colors which cover every portion of the spectrum. Shades of red, orange, yellow, brown, black and grey are the cheapest to use because the pigments themselves are the least expensive and relatively little is needed to achieve good coloring. Brilliant deep yellow and deep shades of blue and green on the other hand are more difficult to provide.

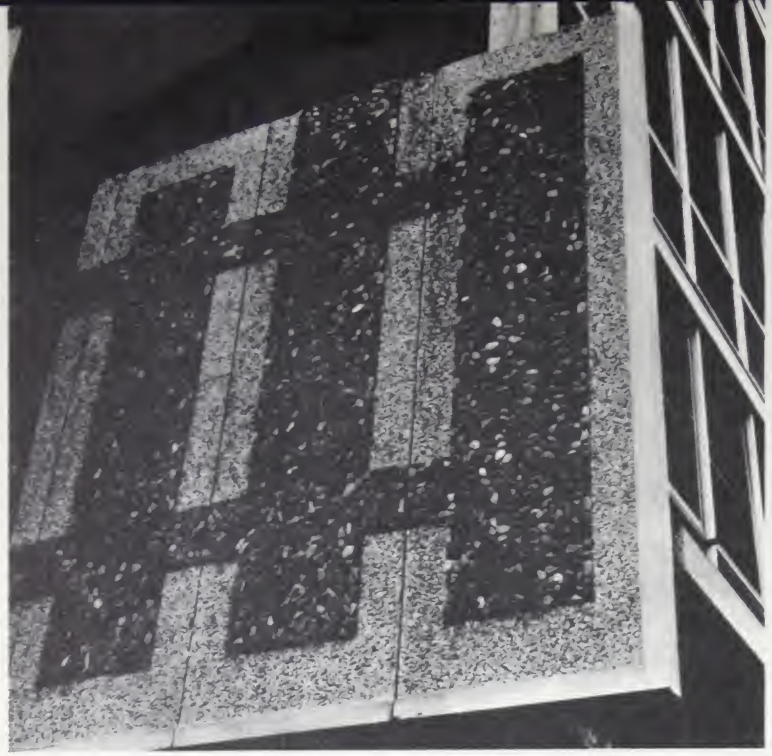
Color should never be used on a plain concrete surface particularly if a series of panels are to be manufactured, because there is always the chance that some variance in batch-to-batch mixing will occur. The exception to this is, of course, when white cement with its uniform whiteness is used. It is always preferable to use white cement as the tinting base for the pigment. This helps reduce the chances of variation. But white cement is expensive; so many producers use standard grey cement and create a patterned or fluted effect rather than present an entire plain surface. In this way any lack of uniformity in tone can be masked by the shading and depth effects induced by the pattern on the surface.

Colored concrete is probably most effective when it is used with an exposed aggregate finish. The blending of color with texture can then be so arranged as to bring out the natural beauty of any aggregate.

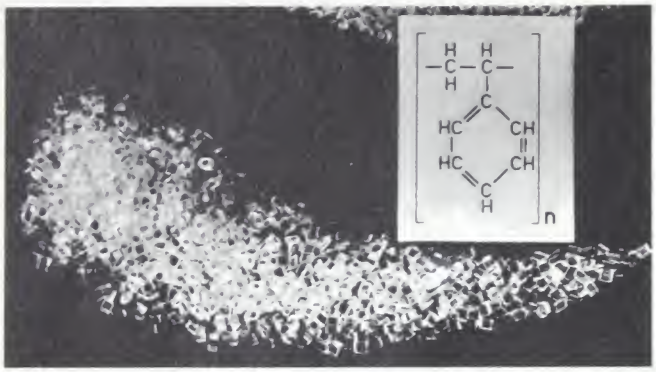
Aggregate of all types can be used. Rocks, shells, glass, plastics, ceramics, and even ball-bearings and brass nuts and bolts have been used at one time or another for exposed aggregate finishes. The most common materials, however, are quartz, marble, granite and some ceramics.

Right: Ceramic aggregates have been used here to provide a decorative, colorful effect





Here, large and small, light and dark-colored stones are blended from panel to panel in an attractive manner



These are plastic granules used in Europe to give texture and sparkle to concrete surfaces. Rough, irregular chips have also been used but at a greater cost. This development is just barely out of the experimental stage

► Quartz aggregates are generally available in three varieties—clear, white and rose (a light pink). Clear quartz is widely used as a sparkling surface to compliment the color effect created by the use of pigmented concrete. The aggregate, because of its neutrality, is then adaptable for use with any color. Similarly, the sparkling advantage can be exploited by including a proportion of clear quartz with aggregate of another color to emphasize, or to avoid playing down, the color of the cement matrix. White quartz ranges from a translucent white, verging on the clear type, to a deep milky white. Rose quartz gives finishes ranging from a delicate pink to a warm, aged-looking rose color.

► Marble, among all aggregates, probably offers the widest selection of colors. The range covers green, yellow, red, pink, blue, grey, white and black. In most areas, blue and yellow marble aggregates are available in pastel hues, and the other colors in many shades running from light to moderately dark.

► Granite, long known for its durability and beauty, is also very popular. It is available in shades of pink, grey, black and white and is usually composed of 30 percent quartz and 70 percent feldspars.

In some parts of the country gravels can be used to provide attractive brown or reddish-brown finishes; they are naturally the lowest priced of all aggregates.

► Ceramic and vitreous materials are the commonest of the manufactured aggregates. They feature a richness, luster and intensity of color not readily achieved with the straight natural aggregates. Cost is normally higher than for the naturals, and manufactured aggregates are usually used for murals, signs and other applications which require a specific, eye-catching beauty. The cost of ceramic materials is from three to five times that of marble, and vitreous aggregate, supplied uncrushed, cost approximately twice as much. One American manufacturer sells his glass aggregates packaged in 100-lb. paper bags for prices ranging from $22 to $42 per hundred weight for quantities from 100 to 400 lb.

When cast with an acid-resisting cement a surface is provided which will be inert to all mineral acids; this opens a wide field of application for

Left: Mosaic tiles, stuck to kraft paper, are being laid down prior to pouring the concrete panel. The process, originated in Sweden, has also been used in the U. S.

heavy industrial exposures where color is often most needed.

Vitreous or glass aggregate has aroused some controversy in the United States. Its brilliant range of colors is appealing, indeed, but its cost tends to dampen enthusiasm.

The advantages of a glass aggregate are that it provides color uniformity from panel to panel and that glass gives the precaster colors that are not obtainable with any natural material. Attractive results are also possible by mixing glass with other materials such as quartz or granite.

On the other hand, the disadvantages of glass, say some producers, are threefold:

(1) Unless the size and shape of the individual glass particles are closely controlled, they do not make concrete with as high a compressive strength as concrete made with a hard aggregate such as quartz.

(2) If relatively large-size (around ¾ in.) glass aggregate is used, the thin precast concrete panel may bow because the glass absorbs and retains heat when exposed to the sun.

(3) Finally, there is the possibility that thin slivers, unless they are removed, will be a hazard to those who handle the glass or the panel. One Midwest precaster, however, found that this was not enough of a problem to deter his use of glass.

All in all, glass provides another intriguing material for architecturally glamorizing the face of a concrete panel.

In many countries geologically less blessed than the U. S., cheap aggregates are given a colored coating, usually by stove enamelling. In Britain, flint stones have been found best for processing in this way and there is a sizeable industry engaged in doing it. The result is an aggregate with a characteristic luster which, provided the proper stoving conditions have been applied, is frostproof, weatherproof and self-cleaning. The best effects are obtained with the primary colors, but satisfactory tones and hues are also possible. These coated aggregates are more expensive than untreated stone chips but, depending upon local conditions, they can be much cheaper than imported stone.

► Plastic chips or granules are also growing in popularity for use as exposed aggregates, particularly in Germany and mainly as the result of the promotional efforts of one of the large chemical companies. Polyester resin chips and polystyrene granules are two of the most commonly used materials. Polyester resins are also used as binders in place of cement for surface coatings. Finishes are either left as cast or ground smooth. The plastic chips are either mixed in or sprinkled over the surface of the unhardened concrete. Most of these plastic aggregates are used in sizes less than ¼ in., although 1-in. pieces have been used for special effects. The normally clear plastic raw materials can be pigmented and filled during production to give a full range of colors, either transparent or opaque. In Europe, prices for plastic are often competitive with stone; and the finishes achieved, far from being looked on as substitutes, have a special attraction of their own.

Exposing the aggregate, be it stone, plastic, glass or any one of a number of materials can be done in several ways. Brushing of the surface while the concrete is still soft is the simplest and least expensive method. If the mix contains ordinary portland cement, brushing can best be done up to 16 to 18 hours after casting. The time depends upon the temperature. The brushes used for the purpose should be stiff bristled ones, and plenty of water is needed during the brushing to ensure that each aggregate particle is cleaned. It is difficult, however, to obtain an even exposure with the brush and water method unless a great deal of time and care is taken. In any event, the method is labor-consuming and producers today, more often than not, use a retarder.

There are many proprietary retarders on the market, but a good retarder should only retard the set, not kill it. A typical retarded mortar if kept moist will harden within 28 days and have excellent strength by 90 days. Since the action of a retarder is a chemical one, the presence of an accelerator, heated concrete or hot weather will reduce the time during which it is effective.

The depth of the retarding action—usually ⅛ in.—depends simply on the thickness of the application and the strength of the concrete at the time the mortar is removed. When the retarder is brushed or sprayed over the plastic concrete the ⅛-in. depth is usually obtained by removing surface mortar within 12 to 24 hours after the concrete has been placed. Deeper penetration is possible by using a heavier coating of the retarder or by removing the surface mortar earlier. A jet of water from a garden hose or a stiff brush and plenty of water are usually employed to remove the mortar. A very coarse carborundum stone together with wet sand can be used if necessary for obstinate patches. Concrete placed with a low slump and good mechanical vibration is preferred.

Commercial retarders are usually clear liquids to which a dye is added to assist even application. They can be so formulated in such a way that when they are applied to forms they will dry to a tough, water-insoluble, abrasion-resistant film.

Retarders, however, do have one disadvantage, particularly when large areas are involved: Due to the intangible nature of the action, the effectiveness of the treatment cannot be assessed until the concrete has hardened; by this time it is too late to take any remedial measures. There is no really satisfactory way to patch a faulty area, although shot-blasting at an early age is about as good as any method. The alternative is to bush-hammer the whole surface which will give an entirely satisfactory result but, of course, at much greater cost.

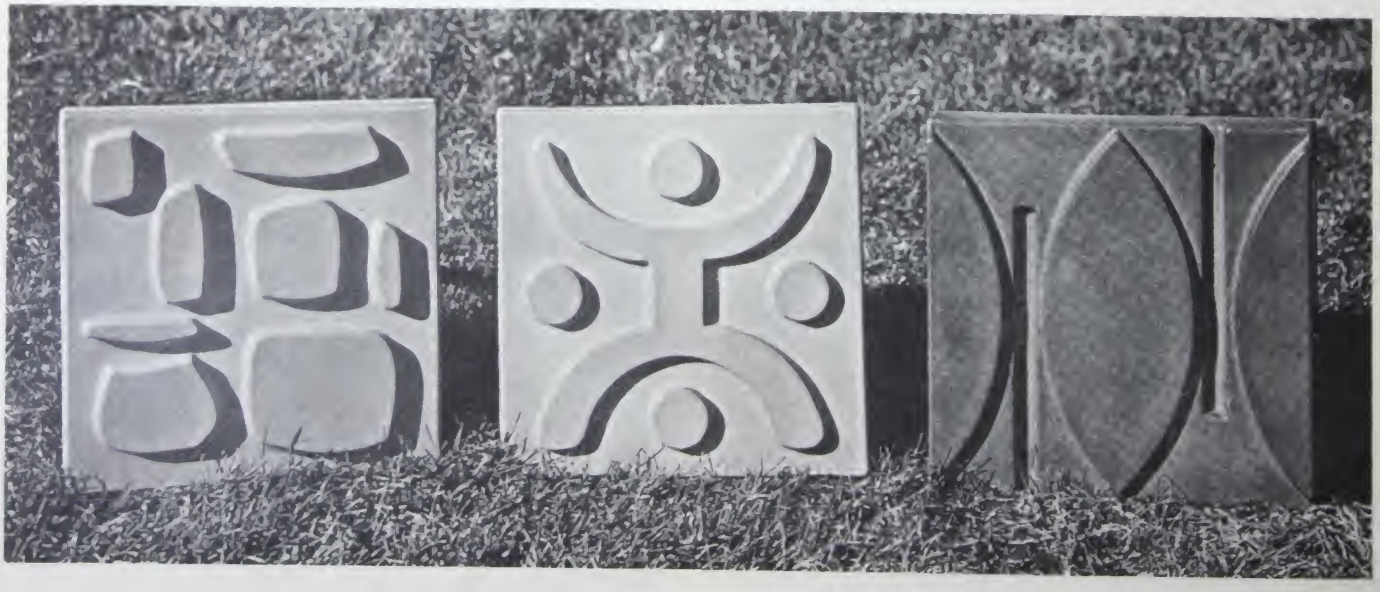
The aggregate transfer technique provides a more positive means of exposing aggregate. Using this technique, expensive special aggregates are confined to a thin surface layer of the concrete and this means that an attractive finish can be economically obtained. Briefly, the technique is as follows: The special aggregates are set in a water-resistant adhesive on a form liner. The liner is fitted within the form (or mold) and the concrete is placed and cured. In this way the aggregate to be exposed becomes embedded in and bonded to the concrete to such an extent that it is transferred from the liner to the mass concrete to provide a durable surface finish. Various special textures are possible by different methods of liner preparation and by grinding or otherwise treating the exposed concrete surface.

One-quarter inch thick plywood is usually the most satisfactory material for a liner although sheet metal, cardboard or heavy waterproof paper is also suitable, particularly when curved surfaces are involved. Plywood is rigid enough to be handled and installed without disturbing the aggregate stuck to it and therein lies its advantage. The maximum practical size for liners is 4 x 8 ft. because this size can be most conveniently handled by two men. With a little care the liners can normally be reused several times.

Prior to use the liner should be oiled lightly. A 50-50 thinned coating of adhesive brushed over it and allowed to dry for 24 hours will protect the surface and increase service life. Strips of wood or heavy waxed cardboard are then fitted around the edges of the liner, if necessary, according to the form or mold characteristics. Similar strips can be fastened to the surface of the liner if a pattern using different colored aggregates is planned. These strips will hold the aggregates to a sharp line, ensure good coverage around the edges, and prevent particles from being dislodged from the edges during handling. If heavy strips are needed for incised forming, or otherwise to mold a pattern, it is advisable only to tack these lightly in position and then to screw them firmly to the liner from the back. When the liner is to be removed, the strips can then be unscrewed and left in place until they can be withdrawn from the concrete without breaking the edges of the pattern.

To apply the aggregate the liner is fixed to a vibrating table and the adhesive spread evenly

These panels, made by using plastic form liners, give the concrete a smooth glass-like surface



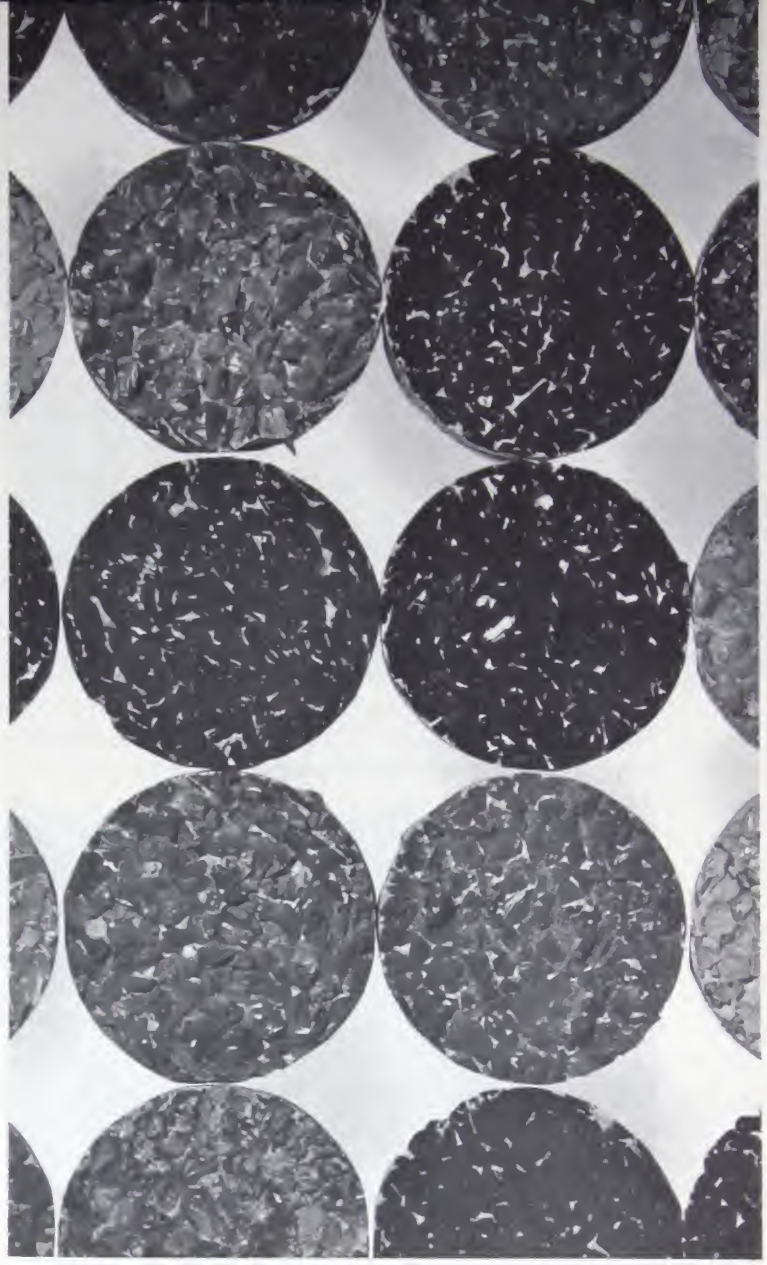
over it. The adhesive to be used must meet several qualifications: It must be waterproof so that it will not be softened by the wet concrete; it must be strong enough so that aggregate particles will not be dislodged during handling or placing the mix. But it should not be so strong that it will damage the liner when it is stripped and thus prevent its reuse.

The aggregate must be spread immediately after the adhesive has been applied because the adhesive tends to skin over in about 20 minutes. During extremely hot weather and especially if the humidity is low, it may be necessary to add a small amount of retarder to the adhesive or to work under cover or early in the day when temperatures are low.

Aggregates should be uniform in size—preferably ¼ to ⅜ in., ⅜ to ½ in. or ½ to ⅝ in.—surface dry and well shaped for adequate embedment in the concrete. Spherical or near-cubical shapes are necessary; thin, flat pieces will not transfer satisfactorily, and sharp irregular particles may be too easily dislodged from the adhesive. The method of placing the aggregate on a liner depends on the size of the area to be covered. Small panels can be covered by hand sprinkling; for larger areas some producers use a V-shaped hopper sized to fit the form. After spreading the aggregate the liner should be vibrated and any additional aggregate needed to complete coverage added by hand. The vibrating table should be one that directs its impulses in a horizontal plane. It also should be adjusted so that it packs and settles the aggregate without causing the particles to roll or jump. Obviously, the particles must not become coated with adhesive on their top or sides or they will not bond firmly with the concrete.

When a pattern of different colored aggregates is to be provided, one color should be spread first and the adhesive allowed to set overnight. The next day the excess aggregate is shaken off, the wooden divider strips removed and fresh adhesive and aggregate spread on the areas that are to be of a different color. This process is repeated for each color used. A drying period of at least 24 hours is recommended before the completed liner is placed in the form; but if the weather is cold or damp, allow more time for the hardening period. In general, the longer the drying period (say 10 to 14 days), the easier it is to strip the liner from the concrete.

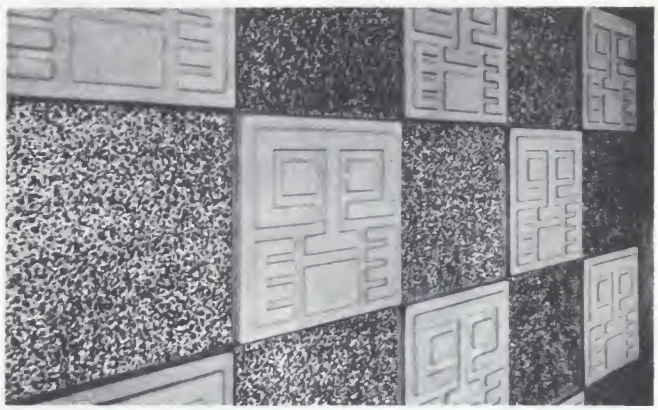
The whole subject of architectural finishes is one which lends itself to experimentation. Unusual and attractive results can often be achieved with the greatest simplicity. For example, several different surface textures may be produced by varying the manner in which the adhesive and aggregate are applied to the liner.



These colored discs, sparkling like rare jewels, are examples of glass aggregates

- To ensure uniform reveal, for instance, use a trowel, with either five or seven points per inch, to spread the adhesive. The larger pitch gives a layer of adhesive suitable for aggregate of ⅜ to ½ in. or ½ in. to ⅝ in., and the smaller for aggregate of ¼ to ⅜ in.
- A rough texture can be produced by using a built-up adhesive such as a mixture of 50 percent plaster-grade perlite and 50 percent adhesive by volume. Because the perlite will absorb some of the adhesive, a thinner must be added to keep the mixture from becoming too viscous. The mix-

These are wall panels made by the Schokbeton process. The brocade-like texture was obtained by combining exposed aggregate and smooth-surfaced concrete



Combining architectural finishing techniques can produce unusual patterns like this one. The sculptured effect on the light-colored panels was obtained using plastic form liners; the variegated panels are of exposed aggregate

Left: This is the Wieboldt store in Chicago; panels have been faced with exposed aggregate in three shades of gray

ture is spread over the liner to a uniform thickness by screeding it with a ⅜ by 1/16-in. steel bar; projecting adjustable pegs near each end can be fitted to allow the thickness to be adjusted as desired. To aid in leveling and ensuring uniformity, the liner should also be vibrated. For ¼ to ⅜-in. aggregate the adhesive layer should be 3/32 to ⅛ in.; for ⅜ to ½ in., 5/32 to 3/16 in. On removing the liner from the hardened concrete, wire-brushing will usually be necessary to remove the excess adhesive.

● Veined finishes can be achieved by applying the adhesive with a toothed trowel and then dashing or spreading a stiff mixture of 10 parts perlite to 1 part of molding plaster over the aggregate-coated liner. Veins or a definite pattern can be produced in this way. When the liner is removed, the weak plaster-perlite mixture is wire-brushed from the surface to give the desired effect.

● A sand finish is also possible by thinning down and brushing out the adhesive so that it becomes little more than a flat wall paint. Sand passing a No. 20 screen and retained on a No. 30 screen is then used as the liner aggregate. This technique is only possible during cool weather or in a cold room, however, because the thin coating of adhesive dries rapidly at higher temperatures.

● Mosaic finishes, a method which originated in Sweden, carries liner production one step further. The mosaic, either marble, vitreous or ceramic, is stuck to strong kraft paper. These sheets are then laid paper-side down in the form and the concrete is cast over it. After the form has been removed from the hardened slab, the paper is easily stripped off the surface and cement grout is applied to fill the cracks between stones. Final washing follows after the grout has hardened. A wide range of colors and designs is offered, and specials are prepared on request. The paper is flexible enough so that it can be made to conform to almost any shape. A similar process has been adopted in Russia for use with tiles up to 2 inches square.

The sand-bed technique, as a method of aggregate transfer, is simpler and easier than the use of an aggregate. Sand-bed production, however, is generally more suitable for use with larger-size aggregates. It's based on casting a panel or other product face downwards. A bed of fine clean sand

is laid over the bottom of the form or mold; the aggregate to be exposed is placed over this, followed by the concrete. Smaller aggregates (less than 1 in., or for round stones less than 1½ in.) are usually simply shoveled into the mold and leveled over the sand-bed to provide a continuous layer and to bond into the concrete as they are best able. Larger sizes, however, are set individually by hand; this ensures full and uniform coverage and, if the workmen are selective, allows the most attractive side of the stones to be exposed to view. The sand-bed technique also enables a colored facing mix to be used, followed by a cheaper, standard-cement mix for the backing. After casting, vibrating and curing, the slab is lifted from its mold and hosed down to remove the sand adhering to it. The sand-bed technique is best used for quality work when an expensive aggregate and a sensitive color matrix are being used.

Hand-pressing of large aggregates into the top surface of freshly filled molds is not unknown. The stones are usually first located lightly in place and then beaten down using either a wooden mallet or piece of board and a hammer. The method is clearly very time-consuming, and is, in fact, only justified for special products. It is not unusual, however, for a client to require a product with two exposed surfaces. This is provided by leaving sufficient space at the top of a mold for a second layer of aggregate, within a matrix of concrete of the desired color, to be spread and pressed into place at final level.

The concrete needed for all exposed aggregate finishes must be workable enough to be readily placed in the interstices of the surface aggregate. Sand in the mix must be well-graded, with 15 to 30 percent passing a No. 50 sieve. An air-entraining agent will also generally be needed. The mix should contain not more than 6½ gal. of water per sack of cement and not less than 5½ sacks of cement per cubic yard of concrete. A slump between 4 to 5 in. is normally most satisfactory. Vibration needs to be applied with care. Internal vibration is more effective than external, but at no time must the vibrator come near enough to the surface to disturb the aggregate. When a facing mix is used, the backing mix should be a very dry, no-slump concrete. This dry mix, then, will tend to absorb any excess moisture from the layer below and ensure a firm bond between the two.

Patching a surface finish created by the aggregate transfer method is possible, and if done carefully is difficult to detect. Imperfections will occasionally arise despite the most careful workmanship, and the use of a repair technique will then permit substantial savings. The patch should be made before any final treatment.

First step is to chip out the defective area to a depth of ¾ to 1 in., undercutting the edges if possible. The surface thus exposed is then wetted and filled with mortar mixed to a stiff consistency with 1 part of cement and 2½ parts sand. The mortar is placed in two layers, each ⅜ to ½ in. thick, on successive days. The second layer is struck off ⅛ in. below the surface, and while the mortar is still soft, grout-coated particles of the matching aggregate are troweled in until an aggregate coverage the same as that on the surrounding areas is obtained. Final step is to compact the patch and float it level with the rest of the surface, and then to cure it for at least five days. The main difficulty lies in matching the color of the patch with the surrounding area. This can be overcome by mixing trial mortars, curing pats of them for five days and then comparing their color with that of the main surface mix to determine which provides the best batch.

The visual aspects of a panel are almost impossible to fully assess before it is in place on the finished structure. There are obviously many psychological factors and pitfalls which affect the difference between the just-acceptable and the exceptional. Essentially, the size and type of aggregate must be selected on the basis of the total area involved and the distance from which it will generally be viewed. Additionally, the contrast desired with the background, or surrounding, materials are important. The color of the matrix in which the aggregate is set will then have considerably greater effect on the final result than is generally realized. This matrix color can, in fact, dominate the entire appearance.

At the same time, the matrix can be made to mute or clarify the aggregate color. Unusual effects can be created by mixing multi-colored aggregates of fairly large size and using a white cement matrix to avoid visual merging of the colors. In general, the larger the area, the lighter the aggregate will appear. Thus the choice of a shade darker aggregate than the sample may be advisable. It is better, too, to introduce dark colors via the aggregate rather than via the matrix.

Lighting conditions can play some unusual tricks, so lighting must be taken into considera-

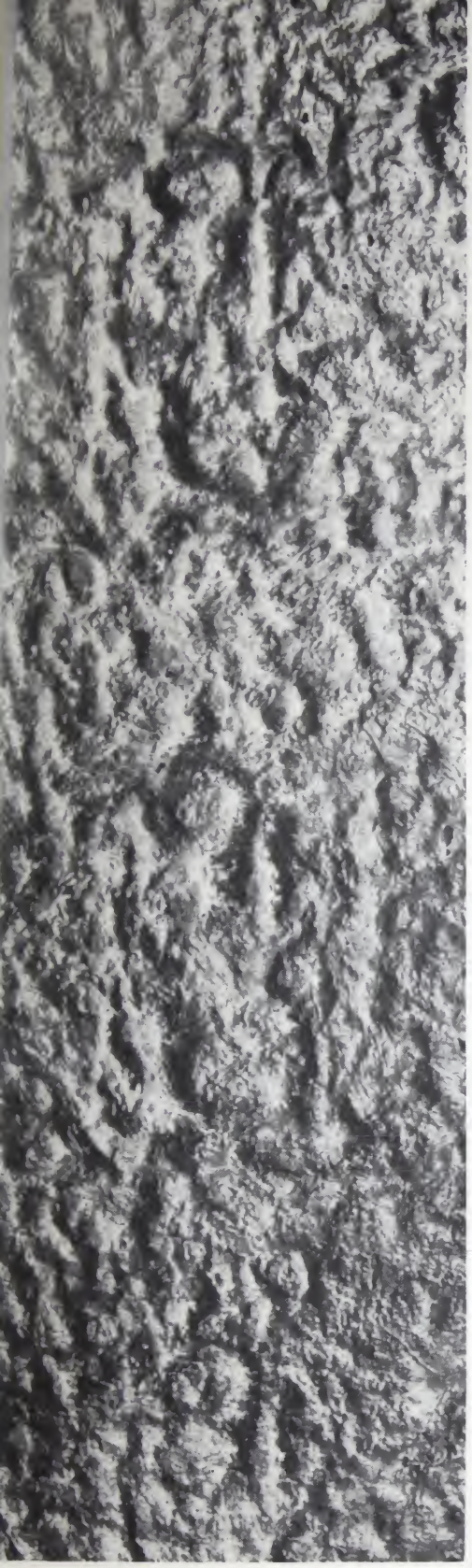
tion. The way light will strike the surface can influence both the apparent shape of the aggregate when in place and the contrast with its background. As might be expected, a moderately rough surface is less obtrusive than a shiny surface. On the other hand, a polished pastel surface will tend to appear white when viewed from afar because of the high reflectance of the surface. Such a treatment would then only be recommended for surfaces close to traffic flow.

Since the aggregates used for facing vary in size—from fine sands up to stones 6 and 7 in. in diam.—the extent to which these are revealed is largely determined by their size. The greater the size the deeper will be the reveal. For the range of sizes in most common use (¼ in. to 1½ in.) reveal is usually about ⅛ in. This depth can be increased by appropriate use of retarders or finishing treatments. The following gives a general idea of the maximum distances at which aggregate will stand out as texture. It must be remembered, however, that these are maxima and that most surfaces will be viewed from distances considerably closer:

3/16 to ¼ in., 60 ft.
¼ to ⅜ in., 75 ft.
⅜ to ½ in., 115 ft.
½ to ¾ in., 200 ft.
¾ to 1 in., 300 ft.
1 to 1½ in., 350 ft.

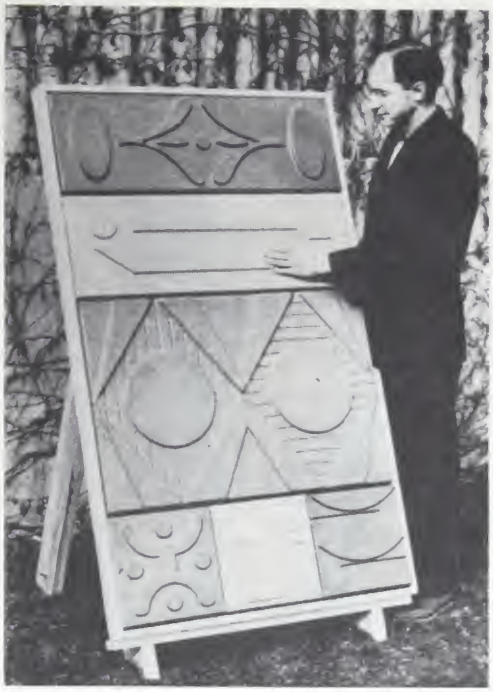
All this must be borne in mind when designing a surface finish. The only real way to be sure of an acceptable result would be to produce experimental slabs within the proposed color and texture range, and then view these from different angles over a range of distances and under different weather and lighting conditions. These techniques are in regular use and a little selective care, effort and thought can give handsome rewards.

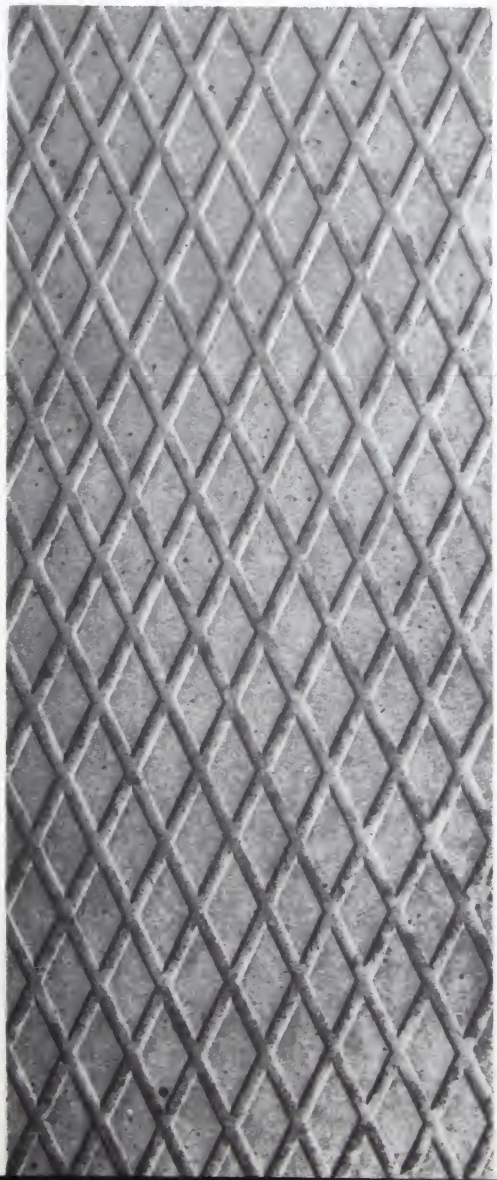
In March, Part II will discuss various patterns and surface treatments that can be applied while the concrete is either in its plastic or hardened state.



Above: This finish was obtained by casting against a textured thermoplastic sheeting

Below: Concrete panels cast with plastic forms have a glossy surface and brilliant colors. Rather intricate patterns can also be cast with plastic forms





Right: The diamond-shaped pattern is probably one of the commonest produced with a rubber form liner

Above: Concrete here was placed in formwork made of green sawn Douglas fir boards

Part 2

Architectural finishes

—a roundup of ideas & techniques

by the Editors of Concrete Products

One of the simplest and least expensive ways of creating an interesting and attractive architectural finish on concrete is to use a pattern—with or without color—in high or low relief. A pattern does not rely on the use of special concreting materials . . . . . and there lies one of its advantages.

Board-marked finishes are one example. Both dressed and rough lumber can be used to show either or both the joint lines and the grain impressions. The quality of the surface will largely depend on the grade and type of lumber used. Douglas fir and long-leaf yellow pine are probably the most popular. They are readily available in sound, straight lengths free from large, loose knots, and both leave a more or less pronounced impression of their grain in the concrete. Sandblasting and rotary wire-brushing are used to bring out the grain in lumber. Slash-grain lumber will also give a very pronounced grain effect. To further heighten the illusion of a wood finish, it is possible on stripping to stain the surface of the concrete brown by means of an acid.

Cupping the boards slightly will accentuate the joint lines. Lumber dressed on one side only (which is then not sized as accurately as when dressed on both sides) will make the effect even more pronounced. To prevent excessive cupping, 6d or 8d common nails should be used, as they have greater holding power than the box nails used with narrower boards. A definite beading along the joint line can be provided by chamfering the internal edges of the boards. The effect is, however, generally more pleasing if it is done with wider boards.

The Germans have developed and just recently introduced a flexible steel-strip formwork. It was designed primarily for columns, but it is possible to adapt it to curved products. In use, the strips are spiral-wound; they are easy to handle and possess a sufficient degree of rigidity on their own to require no intermediate stiffening. To remove the form, the sheet-metal strip is simply unwound and an attractive spiral imprint is presented on the surface. The system (called the Schwellmer System after its originator) has considerable practical advantage in addition to the finish effect it gives.

To most people the board-marked finish is considered a technique limited to site-casting operations. This is certainly not so because precasting within grained timber molds is quite feasible. The use of timber-liners within steel molds is not uncommon, particularly in Scandinavia. More and more manufacturers of plywood in Europe are producing special grades, and textures specifically for concrete work are doing much to enhance the popularity of the material.

For an especially smooth-textured finish, some producers use a plywood that has been smoothed with a plastic filler or lined with a phenolic resin sheet. When applied to high-density exterior grade plywood, the resin-coated surfaces can comfortably stand up to as many as 200 re-uses. For patterned finishes, plywood grades can be purchased which feature a texture of deep, irregu-

larly spaced, full-length grooves for producing one-way or vari-directional cast-in striations. Wire brushing or sand-blasting away of the softer portion of the surface, to accentuate the natural swirls and contours of the grain of the face veneer, are other possibilities. Similarly, a fine pattern texture can be achieved by casting against the screen side of masonite sheets, and chipboard can be adopted to give a characteristic finish. But joints can be a problem with all patterned sheets. The easiest way to overcome this difficulty is to install each sheet, or panel produced, in a checkerboard design. An alternative, which is also very successful, is to plan the finish so that recessed joints—produced by nailing thin wooden battens over the joints between sheets—become an architectural feature on their own.

Rubber form liners provide a more durable but more expensive means of achieving a patterned surface. Rubber form liners can be nailed, clipped and glued into forms and molds. The selection of a non-reactive form oil is the only precaution to be taken with rubber liners. Most rubber is adversely affected by mineral oils so a vegetable oil should be used, particularly if the liner is to be reused. Castor oil and lanolin are two of the most frequently used oils. Form oil is particularly important when rubber form liners are used because it prevents "plucking" of the concrete and gives a clean break without damaging the pattern. If a parting agent is not used, the life of the liner will be seriously reduced and ample setting time must be allowed before stripping.

The most common patterns used with rubber liners are those already in production. The "car-mat" and "street-car platform" designs already carried by manufacturers as roll stock are typical examples. There has also been a trend recently to large studded patterns that are clearly discernible at quite long distances. But regardless of the pattern chosen or requested, it must not have undercut edges or stripping will be impossible. Avoid patterns with a depth greater than ½ in. because placing is difficult and the liner will be much too thick for easy handling. Vibration, whether internal or external, presents no problems when a rubber liner is used although air pockets may be created in an intricate pattern. For this reason, intricate patterns are not recommended.

Plastic form liners are a more recent and much more promising development. They offer satin smooth or textured finishes, in any pattern, with considerable economic advantage. A surface properly cast within a plastic-lined mold will be dense and free of surface voids or water-pockets. The technique also avoids the use of special facing mixes and parting agents and no final grinding or polishing is needed. Because an extremely fine, smooth finish is obtained, integral colors are often considerably more attractive and, due to the high reflectivity, smaller amounts of pigment are needed to obtain a given color intensity. Close temperature control during curing is important, however, if a high degree of reflectivity is to be achieved.

Thermoplastic sheets, with a high gloss on one side and a texture on the other, are also used as form liners. The sheets provide uniform color and appearance, since absorption by the liners is negligible and there is no danger of discoloration from parting agents. Sheets are usually $\frac{1}{16}$ in. thick and supplied in rolls.

The most common materials used for the mold liners are PVC, linear polyethylene and butadiene-styrenes. Size can vary from 1 ft. sq. up to a maximum, by machine limitation, of 4 x 7 ft. Most products' manufacturers will find it more economical to purchase finished liners from a local jobber. Plastics have good mechanical properties and excellent resistance to water, lime and alkalis. Because of these traits, plastics have a fairly long life span. The number of times a mold can be reused seems to vary widely. Much depends upon the type of product being cast, conditions within the plant and how the molds are handled. One plant reports that plastic-lined molds have been used for over 130 castings; others quote an average reuse figure of 23.

Detailed studies by the Portland Cement Association and others have established that a six-sack mix with well-graded aggregates and sufficient fines for a normal good-troweled finish makes the best concrete for use with plastic liners. The minimum size of the aggregate should be consistent with the thickness of the slab, but a ¾-in. grading is the maximum. Slump should be not more than 3½ in. with normal aggregates. Air entrainment is recommended to increase workability and the durability of the finish. The form liner should be clean and dry before use; polishing the liner with a dry towel will increase the gloss of the finish and also extend service life. The gloss of the plastic is, in that way, transferred directly to the concrete so that the use of a parting agent is unnecessary. Many oils are, in fact, detrimental, as they remove the sheen and give a smeared appearance to the cured concrete.

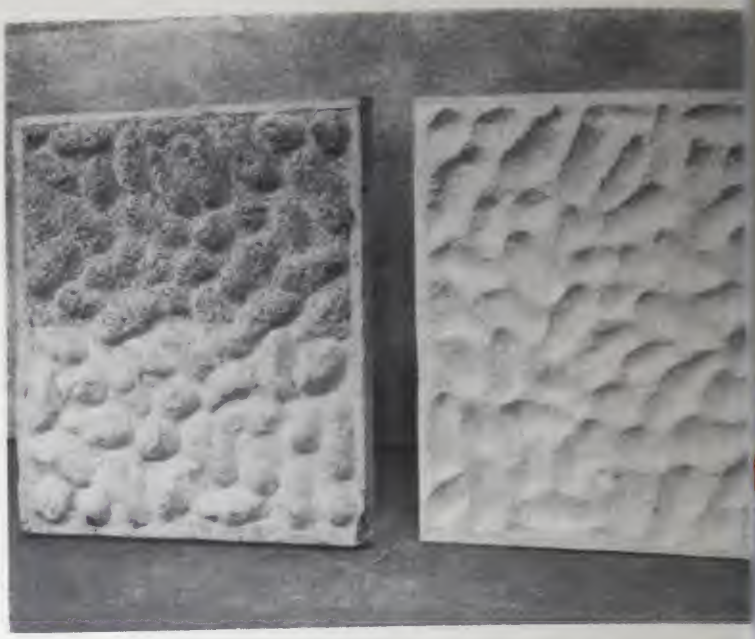
Curing involves some slight precautions. In general, excess moisture will result in practically no gloss, so that curing—under a polyethylene sheet or membrane film, where there will be neither gain nor loss in moisture—is best. For high reflectivity, the temperature during curing must be kept as close to that during casting as possible. The coefficient of thermal expansion of plastics is much higher than that of concrete, and this means that separation of the plastic from the concrete will occur if there is considerable temperature change. For the highest degree of gloss, the temperature change between casting and stripping should not exceed ± 5 deg. F. A greater variation will give a perfectly smooth but a correspondingly duller finish. Curing for a period of 48 hours, and preferably 3 days, is recommended.

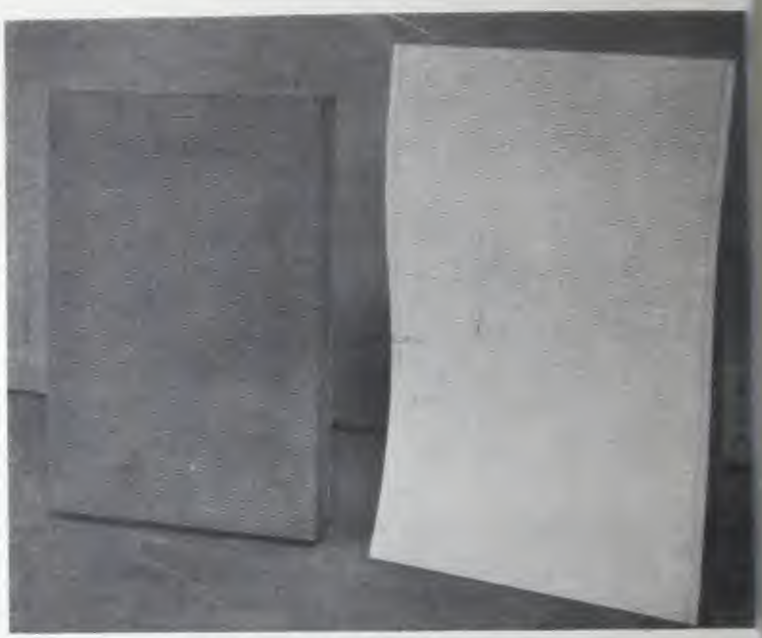
A straight sheet of plastic can be glued and welded to suit any intricate pattern or laminated to lumber quickly and easily. The sheets can also be formed by bending, in the same way as sheet metal. But plastic should be over-bent by about 15 deg. because there is some spring-back when the bending pressure is removed.

Foamed plastics, notably of polystyrene, have also been used as form liners. Cut to random contours, the rough open texture provides an artificial stone effect. With these rigid porous foams it is, however, necessary to use a form oil.

Dimpled surfaces can be created by spreading a layer of stone haphazardly in the bottom of a mold and then covering it with plastic film before placing the concrete. On demolding, the surface will then reveal a softly dimpled effect which, although smooth to the touch, is hard-wearing. The method is extremely cheap and requires no extra skill.

Sculptured art forms, the one-off mural panel type of product, are usually cast by specialists

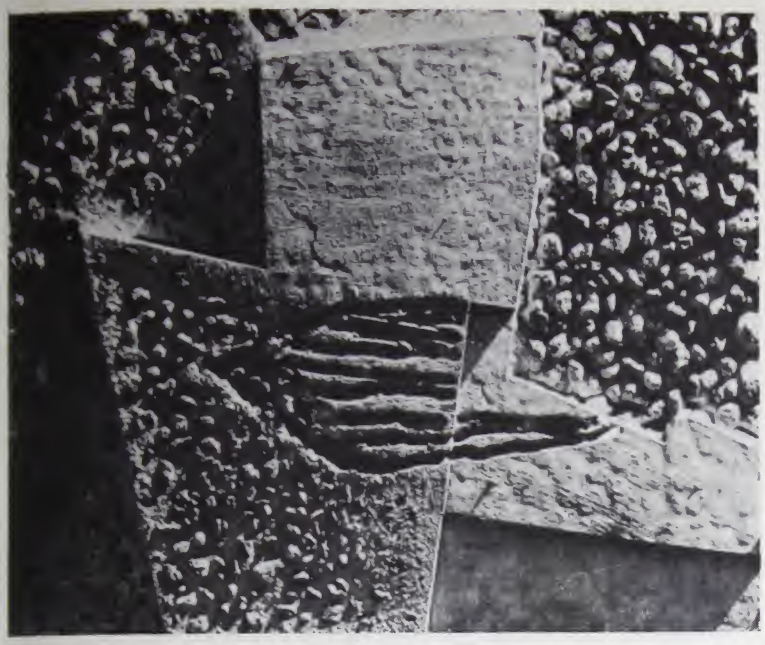




Above: The concrete slab at the left was cast face down against a .020 in. thick vinyl copolymer foil (right) which has a relief pattern produced by vacuum forming against a plaster master. Top half of the slab has been bush hammered to expose the aggregate; lower half shows the concrete surface as cast

Center: Here's another concrete slab (left) cast against a vinyl copolymer foil

Below: This panel was formed by casting against a chipboard form carved and embossed by an artist. Mix was, by weight, 1 part buff portland cement to 6 parts aggregate composed of 40% sand and 60% ¾—⅜ in. gravel



who employ skilled artists and craftsmen. One of the best known ways of casting a sculptured pattern is by means of plaster-of-paris. The artist can either create a negative mold directly in this material, or can form a positive using it, or some other medium, from which the negative mold can be made for casting the final product. Carving directly in chipboard, another art technique, is probably more straightforward—provided the pattern is not too complex.

Yet another technique uses clay and is somewhat more flexible and easier to apply. Briefly, the over-all design is built up from a series of small panels created by troweling, or otherwise tooling out, a negative from a layer of clay. Wooden molds, most conveniently 2 ft. sq., are used to enclose each panel. The clay is spread over the bottom of the mold to a depth of $\frac{3}{4}$ in. or greater, then smoothed to a level surface by scraping with a board. When "carving" of the pattern is finished, glass, mosaic, metals or aggregates which are intended to be exposed on the surface can be embedded in the clay. The mix is then placed and, after curing, mold and clay can be removed to expose the pattern in relief. Color is often applied by pouring pigmented polyester resins, in a very viscous consistency, over selected areas. A simpler and cheaper means of including color is, however, to use certain red, blue, grey and white clays which—when concrete is cast and vibrated over them—will give a permanent stain to a depth of from $\frac{1}{16}$ to $\frac{1}{8}$ in. Hues from terra-cotta to blue-grey are possible in this way which, when allied with the shadows and highlights of the relief, give greater richness than is obtained by the use of pigmented concrete.

There is almost no limit to the way in which concrete, either hardened or while still in its plastic state, can be treated to present an unusual and intriguing finish. Some of these methods produce an effect all their own; others intensify and compliment the finishes described earlier.

Stamping of concrete after it is freshly finished is one of the easiest and cheapest ways of creating

Above: This is the type of texture and decoration it is possible to obtain with the Naturbetong technique—a method of sandblasting concrete

Center: Again, Naturbetong; the repeating pattern here is sandblasted through rubber stencils

Below: Here's a sample of the effect that can be obtained by spreading a plastic sheet over a bed of aggregate and then placing concrete over the plastic film.

an effect. Various tools, usually made of lightweight aluminum, are available to give brick and tile, mesh, grid and other tracery patterns. Special designs can also be fabricated without difficulty. Weighted rollers with a pattern on them in relief have also been used. This approach is favored in Russia where, with the present obsession for more and more mechanization in products' plants, the operators are passing entire wall sections under counter-balanced patterning rollers by means of conveyors.

Outsized metal "cookie cutters" provide a similar method of obtaining an imprinted pattern, and the rims of tin cans of varying diameters can create an interesting random circle effect. A more delicate technique is to provide a "fossil" finish by using a trowel to press large fresh leaves into a surface immediately after final troweling. The leaves are left there until the surface has cured. Yet another series of effects, to simulate flagstones, is possible by pressing random lengths of rough-dressed beading into the surface to form mock joints.

Brooming was probably the forerunner of the present range of abrasive techniques. Straw, fiber and bristle brushes all produce different textures before the concrete has hardened and can be swirled to creat pattern effects.

Rubbing down a nearly hardened surface with canvas, hessian bags or stiff paper, tends to be more arduous but also gives pleasant swirl finishes. These methods all give a surface which is not apparent except at quite close quarters, but they also have an advantage in reducing the formation of surface hair cracks.

Scraping with a steel trowel or preferably a steel comb gives a coarser effect sometimes preferred for its more rural appearance.

Grinding of hardened concrete is the modern high-speed labor-saving equivalent of the old hand-rubbing methods. It should not be attempted until the concrete has cured for at least 14 days. A smooth, almost polished finish can be produced by dry-grinding the surface with a No. 8 grit resin-bonded stone until the aggregate is well exposed. For greatest economy a high operating speed of 4,500 to 5,500 rpm. is recommended. The wheels are best applied at an angle of 30 to 40 degrees, using the weight of the tool alone for pressure. Wet-grinding gives good results but is slower and less economical.

Bush-hammering, like grinding, is expensive and is often restricted to finishes for places where a quality appearance will be of the greatest value. The same minimum 14-day delay before bush-hammering must be observed.

Various types of bush-hammer tool head have been developed for use with concretes: The bush-hammer proper is suitable for use on all concretes, including those with the hardest aggregates; a rotary head is generally preferred since it enables the tool to be rolled over the concrete. An output in excess of one square yard per man-hour is then possible. The texture produced in this way is relatively light because the points on the tool are quite small and the body of the roller prevents too deep a penetration. Appearance will, however, vary according to the type of aggregate present. With hard, crushed-rock aggregates, little or no roller pattern will be discernible, but there is a bruising of the stone which lightens the color. This is more obvious, the darker the stone. No pattern is produced with a natural gravel, and usually there is only a small bruising of aggregate. This is not noticeable because of variations in the color of the gravel (which usually retains its natural smooth surface). With softer aggregates, a pattern invariably shows because the points of the roller penetrate into the aggregate as well as into the matrix.

The point-tool is a single-point chisel which permits extreme variations in texture. The larger the maximum size aggregate used, the coarser the texture one can obtain. For heavily textured concrete, a sharp tool is required with a long-drawn point; for light tooling a short-drawn point, not too sharp is used. The comb-chisel is suitable only for use with the softer aggregates; it is available in various sizes and with various teeth per inch. The effect obtained is of a series of lines cutting through both matrix and aggregate; these lines can be made random or, with the help of a straight-edge, to a pattern of horizontal, vertical or diagonal combings. By "digging-in" with the tool, an undulating texture can also be produced.

A recent development is a triple-headed hammer, each head of which is round but has a cruciform chisel edge. The tool offers the possibility for outputs three times as great as those with the standard bush-hammer.

In Italy and, to some extent, in southern France where labor tends to be less expensive, bush-hammered concrete is rubbed down with pumice. This produces an interesting semi-polished surface

and the technique has grown popular in recent years. A fine (100 teeth per inch) comb-chisel is used for a final smoothing effect before the polishing begins. The surface is more easily kept clean after this treatment but cracks show up easily. For this reason the method has been restricted to relatively small products subject to low stresses.

A texture slightly rougher than that of a bush-hammered surface can be obtained much faster and more economically by sand-blasting. The treatment is particularly suitable for use with precast products since the sand (or shot, as it is called) can be easily collected, cleaned and reused. Sand-blasting is usually done with dry shot in a stream of compressed air. Wet-blasting in a jet of water is preferred, however, in some areas because it presents less of a health hazard.

One sand blast nozzle can treat an area of 300 to 400 sq. ft. However, blasting etches and changes the color of concrete and this must be taken into consideration when sand-blasting is proposed. Test panels should be cast, blasted and the acceptability of the finish assessed before any large-scale operations are begun. This will also provide a chance to select the most suitable grade of blasting sand and to determine the most satisfactory distance from nozzle to surface. Under normal material conditions this distance will be about 5 ft.

The real home of artistically sand-blasted concrete is Norway. Here the famous "Naturbetong" (natural concrete) process was developed to avoid one of the main disadvantages of blasting: the irregular surface texture and appearance which follows from uneven distribution of the coarse aggregate. Naturbetong overcomes this by using in effect "Prepakt" concrete, in which mortar and aggregates are considered as separate entities.

The decorative pattern on these beam units was produced by nailing cedar shingles to the form and then filling the joints between the shingles

The aggregate has a definite grading and all materials under $\frac{5}{8}$ in. are omitted. The mortar used must be so designed and kept under close quality control to minimize internal reduction in volume as a result of creep and shrinkage. This factor—a mortar of consistent volume—is important and can, if neglected, lead under extreme conditions to disintegration.

Two methods of casting Naturbetong are possible: either the mold is filled with the aggregate first and the mortar is added by injection or vibration, or the mortar is placed in the mold first and the gravel is vibrated into place until all the hollow spaces are filled with mortar. The first method is preferred for slender vertical elements, the second for horizontal. With either, the need for exceptionally good forms is obvious. The time element is critical with Naturbetong, since it is the one factor which influences the achievement of an economically sound result. Forms must be removed, and the surface blasted, before the mix has hardened fully. Depending upon temperature and humidity, the usual time for stripping varies between 8 and 20 hours after casting.

Because a special mix is used, the surface finish obtained with Naturbetong is totally different from that of conventional sand-blasted concrete. The difference rests in the presence of a maximum of aggregates, plus the fact that they always lie level, no matter how much or how little of the mortar is blasted away. Extra artistic effects are achieved by varying the force of blast used. Free-hand treatment (almost a type of "engraving") and the use of stencils, together with leaving unblasted sections, are other popular possibilities. Very narrow lines (about $\frac{1}{2}$ in. wide) with sharp edges can be cut by moving the blasting nozzle right close against the wall; the speed of travel then determines the depth of the cut. All blasting must proceed quickly because the concrete hardens steadily and, thus, is more difficult to finish consistently.

To conclude any discussion of surface treatment the practice of etching with a dilute acid must be included. This treatment is used on newly hardened concrete and is valuable as a freshener for any of the more exotic techniques described earlier.

A 10 to 40-percent hydrochloric acid, applied with a brush, is the commonest method of etching. It can be used as early as one day after casting and will remove the thin cement skin and the finest aggregate. A test treatment on a trial slab

of the same composition as that to be etched is recommended because different types of coarse and fine aggregates will not be equally sensitive to the acid. To ensure that the chemical attack will be uniform, the surface should be thoroughly wetted with water before the treatment begins. Acid treatment will proceed normally on marbles and limestones, but with granites, a simultaneous scrubbing with a coarse carborundum stone may be necessary to speed up the process and achieve the desired attractiveness. The final and most important step is to flush off the surface with plenty of clean water both to neutralize the acid and to remove the dissolved material. If there is any doubt whether the neutralization has been completely effective (litmus paper or some similar indicator can be used for testing), the surface should also be washed down with diluted ammonia.

An "architectural" finish then can be achieved in any number of ways and further beauty in concrete is limited only by the imagination of the designer and the economics of production. Casting these two factors aside, the range of possibilities is as wide as one would like to make them—from the imprints of discarded tin cans, to casting with a surface layer of fluorescent plastic chips; from etching with acid, to sand-blasting; from aggregate transfer, to hand spotting.

Partial list of manufacturers & suppliers of special facing aggregates

GRANITE

Tamms Industries, Inc., 228 N. LaSalle Street, Chicago 1, Ill. (black, pink, gray, white)
Wisconsin Granite Co., 111 W Washington St., Chicago, Ill. (pink)
Colonna & Co., Inc., 34-36 Vernon Blvd., Long Island City 6, N.Y. (pink, white, black)
Trimax Corp., Mellen, Wisc. (black)
Dezendorf Marble Co., Box 6032, Austin, Texas (pink, red)
Colonna & Co. of Colo., Box 387, Canon City, Colo. (blue, pink, light gray)
Zanin & Son, Inc., 541 W. 37th St., N.Y. 18, N.Y. (gray, pink)
Rock Products, Inc., of Colo., Box 106, Florence, Colo. (gray, red)

QUARTZ

Stone Products Corp., Box 404, Roanoke, Va. (white)
Colonna & Co. of Colo., Box 387, Canon City, Colo. (milky white, flamingo)
Concrete Specialties Co., 2820 W. 17th Ave., Denver 4, Colo.
Stone & Mineral Corp., Box 186, Merrifield, Va.
Klein & Co., Inc., 1038 W. Peachtree St., N.W., Atlanta 9, Ga. (white)
Architectural Aggregates, Inc., San Saba, Texas
Dezendorf Marble Co., Box 6032, Austin, Texas (clear, milky)
Minnesota Mining & Mfg. Co., St. Paul, Minn. (white)
Tamms Industries, Inc., 228 N. LaSalle St., Chicago 1, Ill. (white)
Colonna & Co., Inc., 34-36 Vernon Blvd., Long Island City 6, N.Y.
Rock Products, Inc., of Colo., Box 106, Florence, Colo. (clear white, pearl gray, ice green, rust green)
Utah Quartz & Rock, Inc., 1103 W. 900 North, North Salt Lake, Utah (quartz and opal)

QUARTZITE

Aggregate Supply, Inc., 640 Wilmington Ave., Salt Lake City 6, Utah
Rock Products, Inc., of Colo., Box 106, Florence, Colo. (blue)
Tennessee Stone Co., Inc., Box 3185, Knoxville 17, Tenn.
Architectural Stone Co., 120 Madeira, N.E., Albuquerque, N.M. (pink, gray, black)

CRYSTALLINE AGGREGATES

Aggregates, Inc., Route 2, Box 834, Golden, Colo. (Wyoming crystaline black)
O. Velardi, 101 Tracy Pl., El Paso, Texas (Mexican crystaline aggregates)
Rock Products, Inc., of Colo., Box 106, Florence, Colo. (crystal black)

ONYX

Utah Calcium Co., 131 W. 1st North, Salt Lake City, Utah (white)
Utah Quartz & Rock, Inc., 1103 W. 900 North, North Salt Lake, Utah
Skyline Supply Co., West Temple & Central, Murray, Utah
Dezendorf Marble Co., Box 6032, Austin, Texas

PEBBLES

Pioneer Pebble & Roofing Rock, Ltd., 5464 W. Washington Blvd., Los Angeles 16, Calif. (white, black, red—pastels—¼ to 8 in.)
Western Materials Co., 33 S. LaSalle St., Chicago, Ill.
Terrazzo & Marble Supply Co., 3018 S. Spaulding St., Chicago, Ill.
Eau Claire Sand & Gravel Co., Eau Claire, Wisc.
St. Louis Material & Supply Co., 7 N. Brentwood Blvd., Clayton 31, Mo.
Missouri-Illinois Aggregates, 2100 N. Wharf St., St. Louis 6, Mo. (brown gravel)
Missouri Aggregates, Inc., 801 S. Lindberg, St. Louis 24, Mo.
Crystal Silica Co., Box 180, Oceanside, Calif. (mixed colors, black, red, green)
Dezendorf Marble Co., Box 6032, Austin, Texas

MARBLE

Alabama Marble Co., Gantt's Quarry, Ala. (white)
Willingham-Little Stone Co., 422 Fulton Federal Bldg., Atlanta 3, Ga. (white)
The Georgia Marble Co., Calcium Products Div., Tate, Ga. (white, gray, pink, green)
Tamms Industries, Inc., 228 N. LaSalle St., Chicago 1, Ill. (white, pink, gray)
Harry T. Campbell Son's Co., Towson, Maryland (white, pink)
Colonna & Co., Inc., 34-36 Vernon Blvd., Long Island City 6, N.Y. (white, cream, black, yellow, green, red, pink, gray, bluish gray, purplish melange)
E. J. Cornelis, 225 W. 37th St., N.Y. 18, N.Y. (pink, light & dark yellow, red, light & dark green, white, black)
Universal Marble Products Corp., Thornwood, N.Y. (white)
Dezendorf Marble Co., Box 6032, Austin, Texas (white, pink, yellow, green, red, gray, black)
E. C. Rockwell, Sales Agent, Box 163, Brandon, Vt. (pink, cream, white)
Wisconsin Marble Co., Inc., 212 W. 2nd St., Ashland, Wisc. (light blue)
Metro-Nite Co., 3523 N. Silver Spring Dr., Milwaukee 9, Wisc. (white)
Knoxville Crushed Stone Co., 121 Stone Rd., Knoxville 20, Tenn. (light Tenn., pink Tenn., special dark pink, dark cedar)
John J. Craig Co., Box 631, Knoxville, Tenn. (Craig pink, dark cedar, light pink)
Jamison Black Marble Co., Box 404, Roanoke, Va. (raven black)
Utah Quartz & Rock, Inc., 1103 W. 900 North, North Salt Lake, Utah
Maryland Green Marble Co., Box 404, Roanoke, Va. (Cardiff green)
Appalachin Marble Co., 2607 Middlebrook Pike, N.W., Knoxville, Tenn. (dark pink, light pink, dark cedar)
Williams Lime Mfg. Co., Hamilton Bank Bldg., Knoxville, Tenn. (dark pink, light pink, dark cedar)
Bland's Marble Chip Co., 1759 W. 5th St., S., Salt Lake City, Utah
Royal Green Marble Co., Phillipsburg, N.J. (royal green)
Swanton Lime Works, Inc., Swanton, Vt. (champlain red, dark pearl gray)
Vermont Marble Co., 61 Main St., Proctor, Vt.
Marble Products Co. of Georgia, 701 First National Bank Bldg., Atlanta 3, Ga.
Klein & Company, Inc., 1038 W. Peachtree St., N.W., Atlanta 9, Ga. (white)
Concrete Specialties Co., 2820 W. 17th Ave., Denver 4, Colo.
North American Non-Metalics, Chewelah, Washington (also Valley, Wash.) ("Na-No-Me" marble)
Terrazzo & Marble Supply Co., Inc., 1-13 Mt. Prospect Ave., Box 1, Clifton, N. J.
Carthage Marble Corp., Box 612, Carthage, Mo.
Zanin & Son, Inc., 541 W. 37th St., N.Y. 18, N.Y. (Cardiff green, raven black, white, Craig pink, cedar, light pink, American Botticino)
Guidicy Marble, Terrazzo & Tile Co., 3801 Eiler St., St. Louis, Mo. (red, pink, Botticino, golden vein, blue gold, rose & red fleuric)
Sonora Marble Aggregates Co., 111 S. Maple St., South San Francisco, Calif.
Arizona Natural Rock Co., Phoenix, Ariz.
Paul H. Guidley Quarries, RFD #1, Pevely, Mo.
Wisconsin Marble Heights Quarries, Inc., Grandview, Wis.
Terrazzo & Marble Supply Co., 3018 S. Spaulding St., Chicago, Ill.
Caribbean Marble Co., 7232 S.W. 42nd St., Miami, Fla.
Oklahoma Tile Co., Inc., 39 N.E. 29th, Oklahoma City, Okla.
Rock Products, Inc., of Colo., Box 106, Florence, Colo. (pink, red, cream, gray)

GLASS

American Porcelain Enamel Co., 1285 E. Keating Ave., Muskegon, Mich. (APEC Brilliants: black, amber, purple, blue, green, white, red, orange, brown)
Rouse & Shearer, 17 Muirhead St., Trenton, N. J. (any color to order)
Glass Tech., Inc., Decatur, Texas
U. S. Mosaic Corp., 2827 John P. St., Detroit, Mich.

SPECIAL HARD AGGREGATES

Norton Co., Worcester, Mass. (Alundum: brown, buff, gray, green, cream, red, black)
Carborundum Co., Niagara Falls, N.Y. (Carborundum: brown, gray, buff, cream, green, red, black)
Creamery Package Mfg. Co., 1243 W. Washington Blvd., Chicago, Ill. (Emery)

SILICA SAND (WHITE)

Ottawa Silica Co., Box 437, Ottawa, Ill.
North Jersey Quarry Co., 10 Park Pl., Morristown, N. J.
Tamms Industries, Inc., 228 N. LaSalle St., Chicago 1, Ill.

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